Does the Stock Market React to Unexpected Inflation Differently Across the Business Cycle?

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Abstract

I find that nominal equity returns respond to unexpected inflation more negatively during contractions than expansions. In particular, returns on firms with lower book-to-market ratio, or of medium size, demonstrate strong asymmetric correlations with unexpected inflation across the business cycle. The cross-sectional correlations of returns on book-to-market and size portfolios with unexpected inflation reflect mostly the heterogeneous factor loadings of these portfolios on one of the Fama-French factors, namely, the excess market return. By examining the cyclical responses to unexpected inflation of the three primitive forces which determine stock prices: the discount rate, the expected growth rate of real activity, and the equity risk premium, I find that changes in expected real activity and the equity premium, signalled by unexpected inflation, are important in explaining the asymmetric responses of the stock market to unexpected inflation across the business cycle.

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1 Introduction

Nominal equity returns have been negatively correlated with unexpected inflation in the postwar U.S. This pattern has been documented in numerous studies, including Fama and Schwert (1977), Fama (1981) and Fama and Gibbons (1982). In this paper, I study the correlations between unexpected inflation and nominal equity returns of Fama-French book-to-market and size portfolios across the business cycle. The paper aims to address the following questions:

1. Does the stock market react to unexpected inflation differently across the business cycle? Equity returns of what types of firms respond more negatively to unexpected inflation? Are these responses asymmetric across the business cycle?

2. What are the reasons behind the cyclical and cross-sectional patterns of the correlation between nominal equity returns and unexpected inflation, or equivalently, inflation beta?

I focus on Fama-French book-to-market and size portfolios for the following reasons: First, one measure for the success of a multi-factor model is whether it can explain the cross-sectional variations in the returns on the book-to-market and size portfolios. Likewise, any structural model successful in explaining the cross-sectional patterns of inflation beta should be able to account for the correlation between returns on these two portfolios and unexpected inflation. This paper starts with documenting the facts. Second, there has been considerable interest in understanding the fundamental nondiversifiable risk that is proxied by the size and value premium related to the two portfolios. Fama and French (1995) suggest some sort of "distress" or "recession" factor at work. This paper sheds light on what type of fundamental nondiversifiable risk may be behind the negative correlation between the stock return and unexpected inflation.

I find strong evidence that nominal equity returns of firms with lower book-to-market ratio, or of medium size are more negatively correlated with unexpected inflation. These are also portfolios whose correlations with unexpected inflation demonstrate strong asymmetric patterns across the business cycle. Namely, returns on these portfolios decline in response to unexpected inflation in recessions, but respond to a much lesser degree in expansions.

In order to examine the fundamentals behind the cyclical and cross-sectional patterns of inflation beta, I use a four-factor model to break inflation beta into components related to each of the common factors. These four factors are: the three Fama-French factors (1993, 1996), excess market return, size and value premium, and the momentum factor introduced by Carhart (1997). It is interesting to examine whether all, or any of the four factors can help to explain the cross-sectional correlations between returns on the size and book-to-market portfolios and unexpected inflation. If the answer is yes, the cross-sectional inflation beta of these portfolios may reveal information about the underlying fundamental risks represented by theses four factors. I orthogonalize the four factors to isolate fundamentals behind each factor. A surprising finding emerges: The excess market return is the only factor that responds to changes in expected and unexpected inflation. Moreover, the excess market return responds more negatively to unexpected inflation during economic contractions than expansions. Correspondingly, the portfolios with higher loadings on the market return factor, specifically those with lower book-to-market ratio, or of medium size, demonstrate both stronger negative response to unexpected inflation, and more salient business cycle asymmetry in their responses. These results indicate that the cross-sectional and cyclical patterns of inflation betas across book-to-market and size portfolios reflect mostly their heterogenous factor loadings on the common factor—excess market return.

In order to explain the cyclical response of the excess market return to unexpected inflation, I follow Boyd, Hu and Jaganathan (2005) and Campbell and Mei (1993) in examining three primitive factors determining stock prices: the discount rate, the expected growth rate of real activity (hereafter, "growth expectations"), and the equity risk premium. Since unexpected inflation affects stock prices, it must convey information about one or more of these primitives.

The cyclical patterns of inflation beta cannot be explained solely by the information about future discount rates that is contained in unexpected inflation. The nominal returns on the 30-year government bond declines in response to unexpected inflation and the magnitude of responses does not differ significantly across the business cycle. It appears that increases in discount rates caused by unexpected inflation in part explain the negative correlation between nominal equity return and unexpected inflation, but not the asymmetry of this correlation across the business cycle.

To examine the importance of growth rate revisions in the cyclical patterns of inflation beta, I study the cyclical responses of utility stocks to unexpected inflation. Growth revisions are relatively unimportant for utility stocks compared to the average stock. I find that there are no significant differences in the responses of utility stocks to unexpected inflation across the business cycle. This finding supports the importance of growth rate variations in the business cycle asymmetry of inflation beta.

The equity risk premium is not directly observable. I use an estimate of the equity risk premium, obtained by Christopher Polk and et al. (2003) from the cross section of stock prices, as a proxy. I examine the responses of this cross-sectional risk premium to unexpected inflation across the business cycle. The measure rises significantly in response to unexpected inflation in recessions, but barely responds in expansions. This observation suggests that unexpected inflation signals higher risk premium in recessions. To sum it up, it appears that the information on future growth rates and risk premium are important elements behind the cyclical patterns of inflation beta.

The finding of the asymmetric business-cycle pattern of inflation beta is in sharp contrast to McQueen and Roley (1993, henceforth M&R). They examine the responses of the daily return on S&P 500 to inflation news across three different stages of the business cycle and find little evidence of cyclical patterns. The empirical test in this paper differs from M&R (1993) in several respects. First, they measure unexpected inflation using survey data. Their sample period ranges from September 1977 to May 1988 due to the availability of survey data. In this paper, I use a time-series model to measure unexpected inflation. The sample period covers the period from March 1964 to December 2007. Second, the classification of economic states are different. M&R (1993) define economic states using the detrended monthly industrial production index. There are around 32 months of "high" and "low" states out of their 127 data observations. In this paper, I classify economic states by the direction of economic activity, namely expansion or recession according to NBER business cycle turning points, rather than the level of industrial production. In total, there are 66 months of contractions and 461 months of expansions over my sample period. Third, M&R focus on the response of aggregate return to inflation news. The aggregation of individual stock returns with different sensitivities to unexpected inflation results in a weaker aggregate responses to inflation news. By contrast, the cross-sectional correlation between stock returns and unexpected inflation studied in this paper demonstrate sharper cyclical patterns.

The cyclical responses of stock returns to unexpected inflation echo an important finding of Boyd, Hu and Jagannathan (2005, henceforth BHJ). They find that an announcement of rising unemployment is "good news" for stocks during economic expansions and "bad news" during economic contractions. Fama's (1981) proxy hypothesis suggests that changes in real activity are the reason for the negative correlation between the stock returns and unexpected inflation. It supports the view that the stock market's cyclical responses to unemployment may be closely related to cyclical patterns of inflation beta.

This paper relates to the literature on the relationship between the stock market and macroeconomic fundamentals. Schaller and Norden (1997) examine the switching regimes of the stock market return and its relationship to aggregate economic variables. Silvapulle and Silvapulle (1999) investigate whether the systematic asymmetric behavior of the U.S. unemployment rate can be explained by the stock market. However, these research focuses on the aggregate stock return, while the cross-sectional differences in responses to unexpected inflation are the focus of this paper.

The rest of the paper is organized as follows. Section 2 documents the cross-sectional and cyclical correlations between Fama-French portfolio returns and unexpected inflation. Section 3 examines the three primitive types of information associated with unexpected inflation. Section 4 concludes.

2 Stock Market's Reaction to Unexpected Inflation

In this section, I first measure the unexpected component of inflation. I then document the cross-sectional and cyclical correlations between returns on Fama-French portfolios and unexpected inflation. Finally, I examine the sensitivity of the three Fama-French factors and the momentum factor to unexpected inflation.

2.1 Measure the Unexpected Component of Inflation

The focus of this paper is to examine how stocks respond to unexpected inflation. Some observable proxy for expected inflation must be used. A number of models for predicting inflation have been suggested in the literature. Univariate ARIMA models are used in several papers, including Schwert (1981). Fama (1975) and Fama and Schwert (1977), among others, use the short-term interest rate on a default free discount bond to measure expected inflation under the assumption that the expected real rate of interest is constant over time. Fama (1981) assumes that the ex-ante real interest rate slowly wanders as a random walk. He then treats the difference between the nominal interest rate and the estimated random walk process as a measure of the expected inflation rate[2].

McQueen and Roley (1993) and Pearce and Roley (1988) use forecasts made by Money Market Services International (MMS) to identify the surprise element of the inflation announcement. I do not follow this procedure since MMS forecasts have only been available since November 1977.

Seeking to employ as much data as possible, I use the following time-series model to measure the expected and unexpected component of inflation:

$$\begin{aligned}\pi_t &= c_0 + c_1\pi_{t-1} + c_2\pi_{t-6} + c_3\pi_{t-7} + c_4\pi_{t-9} + c_5\pi_{t-11} \\ &\quad + c_6 u_{t-1} + c_7 u_{t-11} + \varepsilon_t, \end{aligned} \tag{1}$$

where π_t is the monthly CPI inflation rate, and u_t is the monthly unemployment rate.

The sample period covers from February 1963 to December 2007. The independent variables are chosen so that the model has the lowest AIC (Akaike's Information Criterion) and SBC (Schwarz's Bayesian Criterion) values and all regression coefficients are statistically significant[3]. I use residuals from (1) to measure unexpected inflation, π_t^u, and the fitted values to measure expected inflation, π_t^e. Panel A of Table 1 shows the statistics of inflation and estimated unexpected inflation in expansions and contractions. Panel B of Table 1 contains estimates of the first twelve autocorrelation coefficients of the unexpected inflation rates. All these estimates are within two standard errors of zero, which indicates that there are no predictable patterns in the unexpected inflation series.

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[2] I have also used Gibbs sampling method to extract unexpected inflation from the nominal interest rate and inflation series. Alternative measures of inflation, such as the GDP deflator, have been used to examine the robustness of the findings. The results of this paper are robust to alternative measures of unexpected inflation. The results are available from the author upon request.

[3] I have run regressions with additional independent variables, including the 30-day treasury bill return. I only keep those regressors which have statistically significant coefficients.

2.2 The Cyclical and Cross-Sectional Patterns of Inflation Beta

In this section, I examine the responses of the aggregate and cross-sectional nominal equity returns to unexpected inflation using the linear model[4] given below:

$$Y_{i,t} = b_0 + b_1 \pi_t^e + b_2 \cdot D_t \cdot \pi_t^u + b_3 \cdot (1 - D_t) \cdot \pi_t^u + \epsilon_t, \tag{2}$$

where $Y_{i,t}$ represents either the nominal equity return on a given portfolio, or one of the constructed four factors in the next section. D_t denotes the dummy variable that takes on the value one in contractions and zero otherwise. The contractions and expansions are determined by the NBER business cycle dates.

I estimate equation (2) using data for the period March 1964 to December 2007. There are 66 months of contraction and 461 months of expansion during the sample period. Table 2 and Table 3 present the estimates when the dependent variables are respectively equal-weighted returns on Fama-French portfolios formed on the book-to-market ratio and size. The deciles from D1 to D10 represent the portfolios ranked by the book-to-market ratio or size in ascending order.

2.2.1 Portfolios Formed on Book-to-Market Ratio

Table 2 shows the regression results of the equity returns on ten portfolios ranked by the book-to-market ratio on unexpected inflation using the linear model given in Equation (2). Two cases are considered in the regression. The item "asymmetry" represents the case when asymmetric effects of unexpected inflation are considered. For the case of symmetry, no cyclical dummies are used.

Table 2 reveals strong asymmetry across the business cycle in the stock market's reaction to unexpected inflation. In the regressions of the returns of portfolios ranked by the book-to-market ratio, the coefficients of unexpected inflation range from −9.48 (the first decile) to −4.60 (the fifth decile) in economic contractions, while these coefficients range from −2.80 (the ninth

[4] I use a forecasting model to construct a proxy for the unobserved unexpected inflation series. This gives rise to the well-known errors-in-variables problem, meaning that the estimated slope coefficients will be biased toward zero. The direction of bias suggests that the business cycle asymmetry of inflation betas can be even more salient than reported in the regression results.

decile) to -2.01 (the fourth decile) in economic expansions. The portfolios with smaller book-to-market ratio demonstrate stronger asymmetry of the adverse effects of unexpected inflation across the business cycle. The Wald statistics rejects the null hypothesis that the coefficients of unexpected inflation are the same across the business cycle for the four portfolios with the smallest book-to-market ratio.

There are strong cross-sectional patterns of inflation beta as well, when cyclical effects are considered. Table 2 shows that the smaller the book-to-market ratio, the stronger the negative correlation between the nominal equity returns and unexpected inflation at the time of recession. All the coefficients are significant. The wald statistics (with a $p-$value of 0.00) strongly rejects the null hypothesis that the coefficients of unexpected inflation are the same across deciles. The firms with smaller book-to-market ratio are bad hedges for unexpected inflation in recessions.

2.2.2 Portfolios Formed on Size

Table 3 shows the regressions of the equity returns on ten portfolios ranked by size, i.e., the market value of firms. It again reveals strong asymmetry across the business cycle in the stock market's reaction to unexpected inflation. In the regressions of portfolios ranked by size, the coefficients of unexpected inflation are significantly negative in economic contractions, ranging from -9.44 (the fourth decile) to -6.56 (the tenth decile). These coefficients are significantly negative in expansions from the third decile on, ranging from -2.98 (the sixth decile) to -1.92 (the tenth decile). The Wald statistics rejects the null hypothesis that the coefficients of unexpected inflation are the same across the business cycle all the portfolios except the second decile.

Strong cross-sectional patterns of inflation beta emerge as well. There is a clear U-pattern in the correlation between unexpected inflation and nominal equity returns across size portfolios in economic contractions. From the fourth decile on, the larger the size, the weaker the negative correlation between the equity returns and unexpected inflation; while the opposite is true for the first four portfolios. All the coefficients are significant. The wald statistics (with a $p-$value of 0.04) strongly rejects the null hypothesis that the coefficients of unexpected inflation are the same across deciles in recessions. In economic expansions, the null hypothesis that the coefficients of unexpected inflation are the same across the portfolios can be strongly rejected as well.

The coefficients of expected inflation are insignificantly different from zero for all portfolios.

2.3 A Common Factor Explanation

In this section, I examine the fundamentals behind the cross-sectional and asymmetric patterns of inflation beta. Fama and French (1993, 1996) show that much of the cross-sectional variations in returns on portfolios formed on size and BE/ME can be captured by a three factor model. The three factors are: Rm (the excess market return), the value-weighted return minus the one-month Treasury bill rate; SMB (Small Minus Big), the average return on three small portfolios minus the average return on three big portfolios; HML (High Minus Low), the average return on two value portfolios (high BE/ME) minus the average return on two growth portfolios (low BE/ME). Carhart (1997) adds momentum (MOM) to Fama and French (1993)'s three factor model to improve the explanatory power of the model. These four factors are used to examine the relationship between the stock return and unexpected inflation.

In order to isolate the sensitivity of the equity returns to fundamentals behind each factor. I construct four orthogonal factors, Rm, $\widehat{SMB}$, $\widehat{HML}$, and $\widehat{MOM}$. The factor $\widehat{SMB}$ is the residual of an OLS regression of SMB on the excess return, $\widehat{HML}$ is the residual of an OLS regression of HML on the excess return and $\widehat{SMB}$, and $\widehat{MOM}$ is the residual of an OLS regression of MOM on the excess return, $\widehat{SMB}$ and $\widehat{HML}$.

The factor loadings can be estimated by regressing nominal equity returns on these four factors in the following equation:

$$R_{i,t} = g_{i,0} + g_{i,1}Rm_t + g_{i,2}\widehat{SMB}_t + g_{i,3}\widehat{HML}_t + g_{i,4}\widehat{MOM}_t + \omega_t, \qquad (3)$$

where $R_{i,t}$ is the nominal equity return on the ith portfolio.

The linear structure of the multi-factor model makes it possible to break inflation beta into components related to each of the common factors. For the set of independent variables, $\{\mathbf{1}, \pi_t^e, D_t \cdot \pi_t^u, (1 - D_t) \cdot \pi_t^u\}$, as in equation (2), the regression coefficients of $R_{i,t}$ on these variables are approximately equal to a linear combination of the coefficients of the regressions of $\left\{Rm_t, \widehat{SMB}_t, \widehat{HML}_t, \widehat{MOM}_t\right\}$ on them, with the weights equal to the factor loadings.

Table 4 shows the estimation results of equation (2) when the dependent variables are the constructed Fama-French factors. The right side panel of Table 4 reports the estimates when cyclical effects are not considered. A striking result emerges: Only one of the four factors, the excess return, is sensitive to variations in either expected or unexpected inflation. All the regression coefficients of the three other factors are insignificantly different from zero. There are significant cyclical patterns in the responses of the excess market return to unexpected inflation. The coefficient of unexpected inflation is -7.48 in recessions, significant at 1 percent level, and -2.03 in expansions, also significantly different from zero.

Given that the other three factors are not sensitive to inflation, the cross-sectional patterns of the inflation betas of the book-to-market and size portfolios should be explained completely by their heterogeneous factor loadings on the common factor, excess market return. The empirical evidence indicates that the cyclical correlation between the excess market return and unexpected inflation is the key reason for the cyclical patterns of inflation beta across the Fama-French portfolios.

I further analyze the sensitivity of the excess market return to unexpected inflation for different regions of inflation and unexpected inflation. The results are reported in Table 5. In Panel A(B) of Table 5, D_t denotes the dummy variable that takes on the value one when unexpected inflation (inflation) is positive. The results show that the negative correlation between the excess market return and unexpected inflation is robust in the regions of both inflation and deflation, and at times of both positive ($\pi^u > 0$) and negative inflation surprises ($\pi^u < 0$). The difference in the relationship between the excess market return and unexpected inflation occurs across the business cycle regimes, not across regions of positive or negative inflation.

3 Interest Rates, Growth Expectations and Risk Premium

This section explores the cyclical responses of the excess market return to unexpected inflation through three primitive forces which price stocks. Campbell and Mei (1993) have shown that unexpected inflation bundles three primitive types of information relevant for valuing stocks: information about the future discount rates, the future cash flows and the risk premium. They break inflation beta into components attributable to the above three types of information. In order to examine the cyclical patterns of inflation beta, I study whether these three types of information change in response to unexpected inflation across the business cycle.

3.1 Bonds Market's Response to Unexpected Inflation

I start with examining whether the cyclical responses of stock returns to unexpected inflation can be explained solely by the information about future discount rates. If this is the case, stock and bond prices should respond in the same cyclical manner, except for differences that arise due to differences in their durations.

I estimate equation (2) using the holding period return on the 30-year, 10-year, 1-year government bonds, the three month and one-month T-bills. Table 6 shows that almost all the bond returns are not sensitive to variations in unexpected inflation. The null hypothesis that the coefficients of unexpected inflation are the same across the business cycle cannot be rejected at 10-percent significance level for all bonds I study.

To summarize, government bond prices respond to unexpected inflation in different patterns from those of stock prices, thus the cyclical pattern of inflation beta can not be explained solely by the information about future real interest rates. These findings imply that unexpected inflation must be conveying information about the other two primitive forces, namely, future growth rate expectations and the risk premium required for investors to hold stocks. These two forces affect stock prices, but not bond prices, and therefore may account for the differences in their responses to unexpected inflation.

3.2 The Role of Growth Expectations

There is no direct measure of growth expectations. I will use two pieces of indirect evidence to examine the importance of changes in future growth expectations for the cyclical patterns of inflation beta.

First, I follow Boyd et al. (2001) in studying how noncyclical industries react to macroeconomic news. The logic goes as follows: For industries whose dividends are relatively independent of macroeconomic conditions, revisions in their growth expectations should be relatively less important in their responses to macroeconomic conditions than for the average stock. Public utilities is such an industry. Whether the returns of such industries respond differently to unexpected inflation across the business cycle indicates the importance of revisions in growth expectations for the cyclical patterns of inflation beta.

I estimate equation (2), using the return on the utilities industry constructed by Fama and French as the dependent variable. Table 7 summarizes the estimation results. The equity return on the utilities industry responds negatively to unexpected inflation. However, the coefficient of unexpected inflation in recessions is smaller in the absolute value as compared to the corresponding regression coefficients of returns on the portfolios which demonstrate the weakest negative association with unexpected inflation. The fact that the coefficient of unexpected inflation for utilities industries (-4.31) is more negative than that for the 30-year government bond (-2.00) reflects the fact that there are some growth revision effects for utility stocks compared to bonds.

The cyclical differences in the inflation beta are not significant at 10-percent significance level for the utilities industry. This evidence indicates that revisions in growth expectations are important for the equity returns' cyclical responses to unexpected inflation.

The second piece of indirect evidence is taken from the so-called proxy hypothesis. Marshall (1992) predicts that the correlation between unexpected inflation and equity returns will be more strongly negative when inflation is generated by fluctuations in real economic activity than when it is generated by monetary fluctuations. To take an extreme case in which inflation is driven by real impulses, while holding the money growth rate constant. A positive shock to the growth rate of output causes both a positive innovation to equity returns and a positive innovation to the growth rate in the demand for real balances. Since the growth rate in nominal balance is constant, the inflation rate must fall. Hence, the inflation innovation covaries negatively with the equity return innovation. This is the same argument put forth in Fama (1981) and Fama and Gibbons (1982).

Boyd et al. (2005) suggest that rational equity investors would be revising their dividend growth forecasts much more strongly in response to unemployment surprises in contractions than in expansions. If we consider unemployment surprises as indicating fluctuations in real economic activity, their evidence indicates that unexpected inflation is associated with larger downward revisions in growth forecasts in recessions.

3.3 The Role of Risk Premium

The equity risk premium is not directly observable and therefore I have to use a proxy that can be observed. According to Polk, Thompson and Vuolteenaho (2005), a stock's expected return is linearly related to its beta in the cross section. The slope of the relation is the cross-sectional price of risk, which should equal the expected equity premium. They construct a measure of the cross-sectional price of risk to forecast the equity premium series. They find that this measure is highly negatively correlated with the price level of the stock market, consistent with how a high equity premium usually manifests itself. The measure also forecasts the equity premium reasonably well. I therefore employ their measure of cross-sectional price of risk as a proxy for the equity premium.

Table 8 shows the estimation results of equation (2) when the dependent variable is the proxy for the risk premium[5]. The risk premium increases in response to unexpected inflation in recessions, but barely reacted at the time of expansions. The null hypothesis that the coefficients of unexpected inflation are the same across the business cycle is rejected at 8% significance level. The results indicate that rising risk premium in response to unexpected inflation during recessions contributes to lower equity returns.

The investigation of the three primitive types of information behind stock prices points to the importance of the growth rate revisions, and the risk premium in accounting for the cyclical patterns of inflation beta.

3.4 The Role of Monetary Policy

Kaul (1987) shows that there exists a close link between the monetary policy of the Fed and the relations between stock returns and inflation. He shows that the proxy hypothesis put forward by Fama (1981) and Fama and Gibbons (1982) combined with a counter-cyclical monetary response lead to negative stock return-inflation in the post-war period; however, a pro-cyclical monetary policy in the 1930s leads to significant, or even positive relations between stock returns and inflation. Geske and Roll (1983) argue that a reduction in real activity leads to an increase in fiscal deficits, which in turn boosts inflation when the Federal Reserve monetizes part of the debt.

Some tantalizing issues remain in determining the importance of monetary policy in the cyclical patterns of inflation beta. These issues are:

[5] I thank John Y. Campbell for providing me data on the cross-sectional risk premium.

1. Are there cyclical elements in monetary policy? Specifically, does the Federal Reserve respond to the inflation gap or output gap differently across the business cycle? Are there different inflation targets or output targets across the business cycle?

2. Suppose that there are no cyclical elements in monetary policy, does the growth revision or the risk premium respond more strongly to monetary innovations in recessions than expansions?

If there are cyclical elements in monetary policy, we should have observed cyclical responses of bond returns to unexpected inflation, unless there exist other counter-reacting forces, which exactly offset the cyclical patterns. Absence of asymmetry in the responses of bond returns indicate the importance of the growth rate revisions and changes in the risk premium in response to the monetary policy. A full investigation of these issues is outside the scope of this paper, and I leave them for future research.

4 Conclusion and Future Research

This paper studies the correlations between unexpected inflation and nominal equity returns of Fama-French BE/ME and size portfolios across the business cycle. The main findings can be summarized as follows:

1. There is strong evidence that equity returns respond more negatively to unexpected inflation during economic contractions than expansions.

2. Equity returns of firms with lower book-to-market ratio and medium size are more negatively correlated with unexpected inflation. These are also portfolios whose correlations with unexpected inflation demonstrate strong asymmetric patterns across the business cycle.

3. I construct four orthogonal factors, Rm, $\widehat{SMB}$, $\widehat{HML}$ and $\widehat{MOM}$, based on the three Fama-French factors and the momentum factor. The excess return, Rm, is the only factor which responds to changes in expected and unexpected inflation. As a result, the cross-sectional patterns of inflation betas across book-to-market and size portfolios reflect their heterogenous factor loadings on this common factor.

4. The cyclical patterns of inflation beta cannot be explained based solely on how bond prices react to unexpected inflation. The return on the 30-year government bond declines in response to unexpected inflation and the magnitude of responses does not differ significantly across the business cycle.

5. It appears that information on future growth rates and risk premium are important elements behind the cyclical patterns of inflation beta. Specifically, the proxy of risk premium rises more in response to unexpected inflation in recessions as compared to expansions, contributing to the asymmetric inflation beta across the business cycle.

In this paper, indirect evidence has been used in examining the changes in growth expectations and risk premium in response to unexpected inflation across the business cycle. A more accurate measurement of these elements, in the spirit of Campbell and Mei (1993), is the next step of the research.

A Data

A.1 Inflation

Inflation rate is the rate of change in consumer price index. The consumer price index for all urban consumers, not seasonally adjusted (CPI-U NSA), is utilized to measure inflation, which is the rate of change of prices of consumer goods. The inflation measures are constructed by the US Department of Labor, Bureau of Labor Statistics.

A.2 Interest Rates on Bonds

The 30 year, 10 year and 1 year bond returns, and 90 day and 30 day bill returns are respectively denoted as B30RET, B10RET, B1RET, T90RET, and T30RET in CRSP.

A.3 Unemployment Rate

The unemployment rate is the seasonally adjusted civilian unemployment rate from the Bureau of Labor Statistics.

A.4 Fama-French Factors, the Momentum Factor and Portfolios

The Fama-French factors, the momentum factor, size and book-to-market portfolios, and utilities industry portfolios are available at Kenneth French's website.

A.5 Business Cycle Definitions

I use the NBER's dating of business cycles, which is published on their website. The NBER states that a recession is a significant decline in economic activity spread across the economy, lasting more than a few months, normally visible in real GDP, real income, employment, industrial production, and wholesale-retail sales.

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Table 1: Properties of the Estimated Unexpected Inflation

Unexpected inflation is estimated using the following model described in equation (1) in the text:

$$\begin{aligned}\pi_t &= c_0 + c_1\pi_{t-1} + c_2\pi_{t-6} + c_3\pi_{t-7} + c_4\pi_{t-9} + c_5\pi_{t-11} + c_6 u_{t-1} \\ & c_7 u_{t-11} + \varepsilon_t,\end{aligned}$$

where π_t denotes inflation, and u_t is the monthly unemployment rate. I use residuals from (1) to measure unexpected inflation, π_t^u, and the fitted values to measure expected inflation, π_t^e. Appendix A describes the data in detail. I compute heteroskedasticity and autocorrelation consistent standard errors and t-statistics with the Bartlette kernel. In Panel A, I report the mean and the standard error for the mean (in brackets) for inflation and unexpected inflation during expansions and contractions. For unexpected inflation, I also report the mean and the standard error for the mean (in brackets) conditional on whether unexpected inflation is positive or negative during expansions and contractions and the corresponding number of observations (denoted by N). Expansions and contractions are based on NBER's dating of business cycle turning points. Numbers are expressed as percentages. In Panel B, I report the auto-correlation coefficients of the first, till the 12-th order autocorrelation of unexpected inflation. The period covered is February 1963 to December 2007.

Panel A						
	π	π^u	good news ($\pi^u < 0$)		bad news ($\pi^u > 0$)	
	Mean	Mean	N	Mean	N	Mean
Whole sample	0.360	-1.39×10^{-17}				
	[0.035]	[0.010]				
Contraction	0.543	−0.020	33	−0.237	33	0.197
	[0.097]	[0.035]		[0.022]		[0.038]
Expansion	0.340	0.003	243	−0.138	218	0.160
	[0.031]	[0.010]		[0.011]		[0.012]
Panel B						
Auto-correlations	1	2	3	4	5	6
	−0.02	0.02	0.04	0.06	0.08	−0.01
	[0.08]	[0.07]	[0.05]	[0.05]	[0.05]	[0.05]
	7	8	9	10	11	12
	−0.03	−0.01	−0.10	0.10	0.01	−0.08
	[0.05]	[0.04]	[0.05]	[0.06]	[0.06]	[0.06]

Table 2: Regressions of B-to-M Portfolio Returns on Unexpected Inflation

The left panel of the table reports the estimated values of the slope coefficients in the equation,

$$Y_{i,t} = b_0 + b_1\pi_t^e + b_2 \cdot D_t \cdot \pi_t^u + b_3 \cdot (1 - D_t) \cdot \pi_t^u + \epsilon_t.$$

when the business cycle asymmetry is considered. $Y_{i,t}$ denotes the returns on the i-th portfolio ranked by the book-to-market ratio in ascending order. π_t^e and π_t^u represent respectively expected and unexpected inflation, and D_t is a dummy variable which equals 1 during recessions. The p-values for estimated coefficients are reported in the parentheses below the estimates. The p-value in the sixth column reports the p-value of the Wald statistics which tests the null hypothesis $(b_2 = b_3)$. The p-values in the last row are for the Wald statistics testing the hypothesis that the coefficients are the same across deciles. The deciles are ranked according to the book-to-market ratio in ascending order from D1 to D10. The right panel of the table reports the estimated values of the slope coefficients in the equation,

$$Y_{i,t} = d_0 + d_1\pi_t^e + d_2\pi_t^u + \epsilon_t.$$

when the business cycle asymmetry is not considered. I compute heteroskedasticity and autocorrelation consistent standard errors and t-statistics with the Bartlette kernel. The period covered is February 1963 to December 2007.

	Asymmetry					Symmetry		
	b_0	b_1	b_2	b_3	p value $(b_2 = b_3)$	d_0	d_1	d_2
Deciles								
D1	1.58	−2.13	−9.48	−2.30	0.02	1.60	−2.13	−3.74
	(0.00)	(0.13)	(0.00)	(0.02)		(0.00)	(0.14)	(0.00)
D2	1.32	−1.15	−8.52	−2.73	0.04	1.34	−1.15	−3.90
	(0.01)	(0.35)	(0.00)	(0.01)		(0.00)	(0.36)	(0.00)
D3	1.32	−0.98	−7.67	−2.61	0.08	1.33	−0.98	−3.63
	(0.00)	(0.39)	(0.00)	(0.01)		(0.00)	(0.40)	(0.00)
D4	1.46	−1.24	−6.26	−2.01	0.09	1.47	−1.24	−2.86
	(0.00)	(0.35)	(0.01)	(0.07)		(0.00)	(0.35)	(0.00)
D5	1.30	−0.90	−4.60	−2.44	0.35	1.30	−0.90	−2.87
	(0.00)	(0.44)	(0.02)	(0.02)		(0.00)	(0.44)	(0.00)
D6	1.41	−0.89	−5.54	−2.38	0.12	1.42	−0.89	−3.01
	(0.00)	(0.37)	(0.00)	(0.01)		(0.00)	(0.38)	(0.00)
D7	1.57	−1.15	−6.32	−2.59	0.12	1.58	−1.14	−3.34
	(0.00)	(0.25)	(0.00)	(0.01)		(0.00)	(0.25)	(0.00)
D8	1.44	−0.72	−5.67	−2.23	0.12	1.45	−0.72	−2.93
	(0.00)	(0.39)	(0.01)	(0.02)		(0.00)	(0.40)	(0.00)
D9	1.52	−0.73	−5.83	−2.80	0.21	1.53	−0.73	−3.40
	(0.00)	(0.45)	(0.00)	(0.02)		(0.00)	(0.46)	(0.00)
D10	1.93	−1.51	−5.87	−2.49	0.29	1.94	−1.51	−3.17
	(0.00)	(0.20	(0.04)	(0.04)		(0.00)	(0.21)	(0.00)
p value			0.0000	0.51			0.26	0.14

Table 3: Regressions of Returns on Size Portfolios on Unexpected Inflation

The left panel of the table reports the estimated values of the slope coefficients in the equation,

$$Y_{i,t} = b_0 + b_1 \pi_t^e + b_2 \cdot D_t \cdot \pi_t^u + b_3 \cdot (1 - D_t) \cdot \pi_t^u + \epsilon_t.$$

when the business cycle asymmetry is considered. $Y_{i,t}$ denotes the returns on the i-th portfolio ranked by size (market value) in ascending order. π_t^e and π_t^u represent respectively expected and unexpected inflation, and D_t is a dummy variable which equals 1 during recessions. The p-values for estimated coefficients are reported in the parentheses below the estimates. The p-value in the sixth column reports the p-value of the Wald statistics which tests the null hypothesis $(b_2 = b_3)$. The p-values in the last row are for the Wald statistics testing the hypothesis that the coefficients are the same across deciles. The deciles are ranked according to size in ascending order from D1 to D10. The right panel of the table reports the estimated values of the slope coefficients in the equation,

$$Y_{i,t} = d_0 + d_1 \pi_t^e + d_2 \pi_t^u + \epsilon_t.$$

when the business cycle asymmetry is not considered. I compute heteroskedasticity and autocorrelation consistent standard errors and t-statistics with the Bartlette kernel. The period covered is February 1963 to December 2007.

	Asymmetry					Symmetry		
	b_0	b_1	b_2	b_3	p value $(b_2 = b_3)$	d_0	d_1	d_2
Deciles								
D1	2.08	−2.32	−8.13	−1.22	0.08	2.09	−2.31	−2.61
	(0.00)	(0.15)	(0.01)	(0.51)		(0.00)	(0.16)	(0.08)
D2	1.89	−1.99	−8.40	−2.39	0.13	1.91	−1.99	−3.60
	(0.00)	(0.20)	(0.01)	(0.17)		(0.00)	(0.21)	(0.02)
D3	1.76	−1.53	−9.20	−2.73	0.07	1.77	−1.52	−4.03
	(0.00)	(0.28)	(0.00)	(0.08)		(0.00)	(0.30)	(0.00)
D4	1.66	−1.38	−9.44	−2.88	0.06	1.67	−1.37	−4.20
	(0.00)	(0.33)	(0.00)	(0.04)		(0.00)	(0.35)	(0.00)
D5	1.78	−1.61	−9.40	−2.83	0.05	1.79	−1.61	−4.15
	(0.00)	(0.25)	(0.00)	(0.04)		(0.00)	(0.26)	(0.00)
D6	1.66	−1.55	−8.78	−2.98	0.06	1.67	−1.55	−4.15
	(0.00)	(0.22)	(0.00)	(0.01)		(0.00)	(0.24)	(0.00)
D7	1.63	−1.39	−8.52	−2.69	0.04	1.65	−1.39	−3.86
	(0.00)	(0.29)	(0.00)	(0.02)		(0.00)	(0.30)	(0.00)
D8	1.54	−1.29	−8.28	−2.65	0.04	1.56	−1.29	−3.79
	(0.00)	(0.27)	(0.00)	(0.02)		(0.00)	(0.28)	(0.00)
D9	1.42	−1.12	−8.10	−2.15	0.02	1.43	−1.11	−3.35
	(0.00)	(0.32)	(0.00)	(0.03)		(0.00)	(0.34)	(0.00)
D10	1.38	−1.43	−6.56	−1.92	0.05	1.39	−1.43	−2.86
	(0.00)	(0.20)	(0.00)	(0.03)		(0.00)	(0.21)	(0.00)
p value			0.04	0.00			0.13	0.00

Table 4: Regressions of Orthogonalized Factors on Unexpected Inflation

The left panel of the table reports the estimated values of the slope coefficients in the equation,

$$Y_{i,t} = b_0 + b_1\pi_t^e + b_2 \cdot D_t \cdot \pi_t^u + b_3 \cdot (1 - D_t) \cdot \pi_t^u + \epsilon_t.$$

when the business cycle asymmetry is considered. $Y_{i,t}$ denotes the ith orthogonalized factor. The estimation of the orthogonalized factors, $R_m, \widehat{SMB}$,$\widehat{HML}$ and $\widehat{MOM}$ are described in the text. π_t^e and π_t^u represent respectively expected and unexpected inflation, and D_t is a dummy variable which equals 1 during recessions. The p-values for estimated coefficients are reported in the parentheses below the estimates. The p-value in the sixth column reports the p-value of the Wald statistics which tests the null hypothesis $(b_2 = b_3)$. The p-values in the last row are for the Wald statistics testing the hypothesis that the coefficients are the same across deciles. The right panel of the table reports the estimated values of the slope coefficients in the equation,

$$Y_{i,t} = d_0 + d_1\pi_t^e + d_2\pi_t^u + \epsilon_t.$$

when the business cycle asymmetry is not considered. I compute heteroskedasticity and autocorrelation consistent standard errors and t-statistics with the Bartlette kernel. The period covered is February 1963 to December 2007.

	Asymmetry					Symmetry		
	b_0	b_1	b_2	b_3	p value $(b_2 = b_3)$	d_0	d_1	d_2
Factors								
R_m	1.20	−2.07	−7.48	−2.03	0.03	1.21	−2.06	−3.12
	(0.00)	(0.07)	(0.00)	(0.04)		(0.00)	(0.08)	(0.00)
$\widehat{SMB}$	−0.04	0.10	−0.98	0.18	0.55	−0.04	0.10	−0.06
	(0.89)	(0.85)	(0.55)	(0.81)		(0.89)	(0.85)	(0.93)
$\widehat{HML}$	0.06	−0.15	1.16	−0.52	0.18	0.05	−0.15	−0.19
	(0.84)	(0.81)	(0.29)	(0.42)		(0.85)	(0.81)	(0.74)
$\widehat{MOM}$	−0.12	0.34	1.33	1.20	0.96	−0.12	0.34	1.23
	(0.70)	(0.63)	(0.51)	(0.30)		(0.70)	(0.63)	(0.19)

Table 5: Regressions of Excess Market Return on Unexpected Inflation

The left panel of the table reports the estimated values of the slope coefficients in the equation,

$$Y_t = f_0 + f_1\pi_t^e + f_2 \cdot D_t \cdot \pi_t^u + f_3 \cdot (1 - D_t) \cdot \pi_t^u + \epsilon_t.$$

when the cases of positive and negative unexpected inflation are considered. Y_t denotes the exess equity return, R_m,the first orthogonalized Fama-French factor. π_t^e and π_t^u represent respectively expected and unexpected inflation. In Panel A, D_t is a dummy variable which equals 1 when unexpected inflation is positive. In Panel B, D_t is a dummy variable which equals 1 when inflation itself is positive. The p-values for estimated coefficients are reported in the parentheses below the estimates. The p-value in the sixth column reports the p-value of the Wald statistics which tests the null hypothesis $\left(f_2 = f_3\right)$. The right panel of the table reports the estimated values of the slope coefficients in the equation,

$$Y_{i,t} = g_0 + g_1\pi_t^e + g_2\pi_t^u + \epsilon_t.$$

when different regions of inflaton are not considered. I compute heteroskedasticity and autocorrelation consistent standard errors and t-statistics with the Bartlette kernel. The period covered is February 1963 to December 2007.

	Asymmetry					Symmetry		
	f_0	f_1	f_2	f_3	p value ($f_2 = f_3$)	g_0	g_1	g_2
Panel A								
R_m	1.18	-2.09	-2.84	-3.44	0.80	1.21	-2.06	-3.12
	(0.00)	(0.08)	(0.08)	(0.00)		(0.00)	(0.08)	(0.00)
Panel B								
R_m	1.11	-1.93	-2.64	-4.73	0.24			
	(0.01)	(0.10)	(0.02)	(0.00)				

Table 6: Regressions of Bond Returns on Unexpected Inflation

The left panel of the table reports the estimated values of the slope coefficients in the equation,

$$Y_{i,t} = b_0 + b_1 \pi_t^e + b_2 \cdot D_t \cdot \pi_t^u + b_3 \cdot (1 - D_t) \cdot \pi_t^u + \epsilon_t.$$

when the business cycle asymmetry is considered. $Y_{i,t}$ denotes respectively the 30-year, 10-year, 1-year bond returns and 90-day and 30-day Treasury bill returns. π_t^e and π_t^u represent respectively expected and unexpected inflation, and D_t is a dummy variable which equals 1 during recessions. The p-values for estimated coefficients are reported in the parentheses below the estimates. The p-value in the sixth column reports the p-value of the Wald statistics which tests the null hypothesis $(b_2 = b_3)$. The right panel of the table reports the estimated values of the slope coefficients in the equation,

$$Y_{i,t} = d_0 + d_1 \pi_t^e + d_2 \pi_t^u + \epsilon_t.$$

when the business cycle asymmetry is not considered. I compute heteroskedasticity and autocorrelation consistent standard errors and t-statistics with the Bartlette kernel. The period covered is February 1963 to December 2007.

	Asymmetry					Symmetry		
	b_0	b_1	b_2	b_3	p value $(b_2 = b_3)$	d_0	d_1	d_2
Bonds								
30 yr	0.85	−0.62	−2.00	−1.76	0.91	0.85	−0.62	−1.81
	(0.00)	(0.19)	(0.26)	(0.03)		(0.00)	(0.19)	(0.01)
10 yr	0.70	−0.23	−0.09	−0.85	0.63	0.70	−0.23	−0.69
	(0.00)	(0.54)	(0.95)	(0.13)		(0.00)	(0.54)	(0.16)
1 yr	0.34	0.59	−0.40	−0.13	0.41	0.34	0.59	−0.19
	(0.00)	(0.00)	(0.19)	(0.22)		(0.00)	(0.00)	(0.09)
3 month	0.25	0.73	−0.01	0.03	0.83	0.25	0.73	0.02
	(0.00)	(0.00)	(0.96)	(0.53)		(0.00)	(0.00)	(0.63)
1 month	0.22	0.69	0.04	0.05	0.93	0.22	0.69	0.05
	(0.00)	(0.00)	(0.73)	(0.15)		(0.00)	(0.00)	(0.13)
p value			(0.00)	(0.00)			(0.01)	(0.00)

Table 7: Regressions of Returns on Utilities Portfolios on Unexpected Inflation

The left panel of the table reports the estimated values of the slope coefficients in the equation,

$$Y_t = b_0 + b_1\pi_t^e + b_2 \cdot D_t \cdot \pi_t^u + b_3 \cdot (1 - D_t) \cdot \pi_t^u + \epsilon_t.$$

when the business cycle asymmetry is considered. Y_t denotes the return on the utilities industry portfolio. π_t^e and π_t^u represent respectively expected and unexpected inflation, and D_t is a dummy variable which equals 1 during recessions. The p-values for estimated coefficients are reported in the parentheses below the estimates. The p-value in the sixth column reports the p-value of the Wald statistics which tests the null hypothesis $(b_2 = b_3)$. The right panel of the table reports the estimated values of the slope coefficients in the equation,

$$Y_{i,t} = d_0 + d_1\pi_t^e + d_2\pi_t^u + \epsilon_t.$$

when the business cycle asymmetry is not considered. I compute heteroskedasticity and autocorrelation consistent standard errors and t-statistics with the Bartlette kernel. The period covered is February 1963 to December 2007.

	Asymmetry					Symmetry		
	b_0	b_1	b_2	b_3	p value $(b_2 = b_3)$	d_0	d_1	d_2
Utilities	0.79	0.25	-4.31	-1.97	0.22	0.80	0.25	-2.44
	(0.04)	(0.76)	(0.00)	(0.07)		(0.03)	(0.76)	(0.01)

Table 8: Regressions of Risk Premium on Unexpected Inflation

The left panel of the table reports the estimated values of the slope coefficients in the equation,

$$Y_t = b_0 + b_1 \pi_t^e + b_2 \cdot D_t \cdot \pi_t^u + b_3 \cdot (1 - D_t) \cdot \pi_t^u + \epsilon_t.$$

when the business cycle asymmetry is considered. Y_t denotes the proxy of the equity risk premium. π_t^e and π_t^u represent respectively expected and unexpected inflation, and D_t is a dummy variable which equals 1 during recessions. The p-values for estimated coefficients are reported in the parentheses below the estimates. The p-value in the sixth column reports the p-value of the Wald statistics which tests the null hypothesis $(b_2 = b_3)$. The right panel of the table reports the estimated values of the slope coefficients in the equation,

$$Y_{i,t} = d_0 + d_1 \pi_t^e + d_2 \pi_t^u + \epsilon_t.$$

when the business cycle asymmetry is not considered. I compute heteroskedasticity and autocorrelation consistent standard errors and t-statistics with the Bartlette kernel. The period covered is February 1963 to December 2003 (due to data availability).

	Asymmetry					Symmetry		
	b_0	b_1	b_2	b_3	p value $(b_2 = b_3)$	d_1	d_2	d_3
proxy of risk premium	-0.20	-0.11	0.15	0.00	0.08	-0.20	-0.11	0.04
	(0.00)	(0.09)	(0.07)	(0.87)		(0.00)	(0.11)	(0.19)